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Power Handling of the Bulk Tungsten Divertor Row at JET: First measurements and comparison to the GTM thermal model

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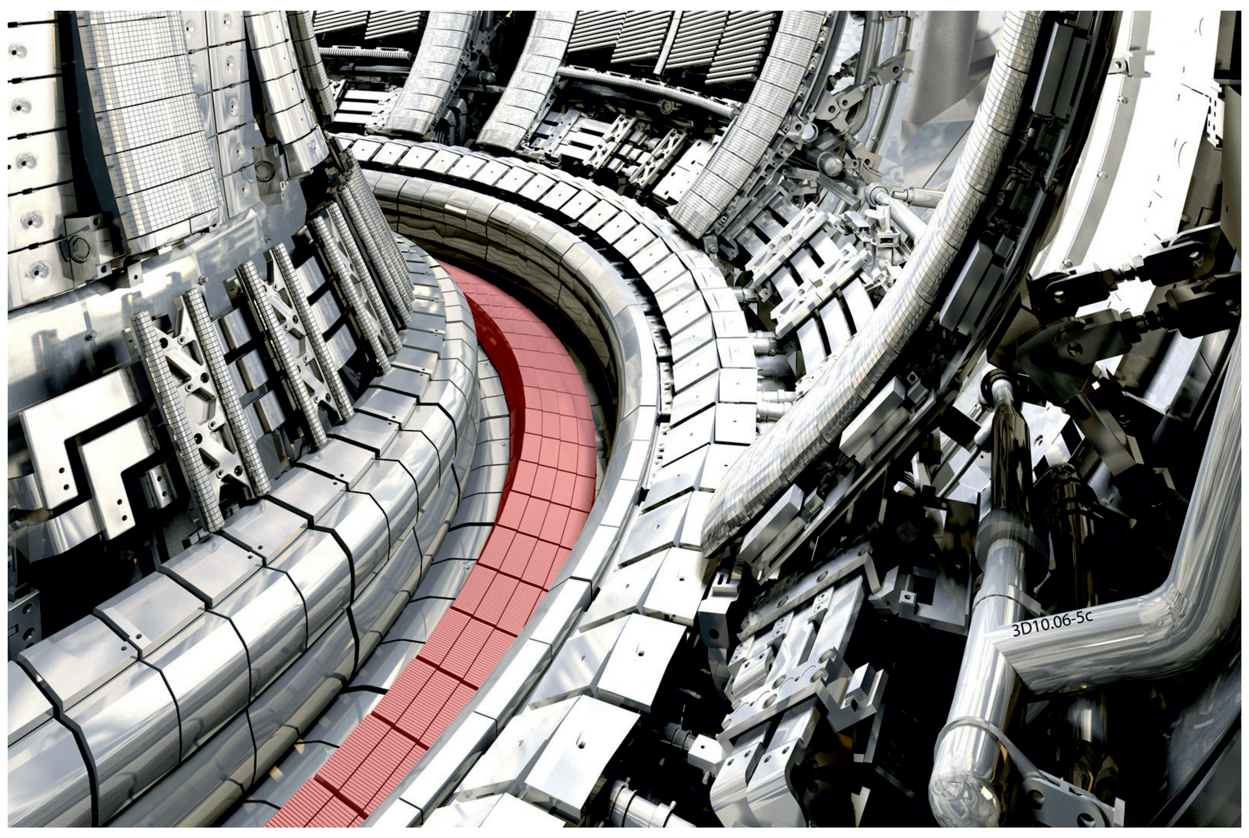
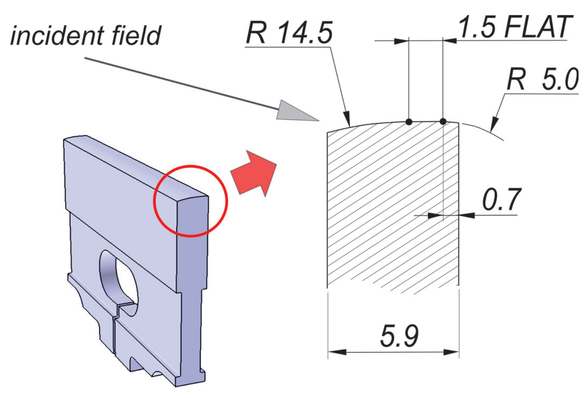
**See the Appendix of F. Romanelli et al., Proceedings of the 24th IAEA Fusion Energy Conference 2012, San Diego, USA*

1 Introduction

The divertor of the new JET ITER-like Wall (ILW) currently includes a solid tungsten row [1] for the outer strike point – indicated in red colour below.



- The design of the tile assemblies of the bulk tungsten divertor row in JET was improved in the course of several experiments with respect to the power and energy performance: high heat fluxes (HHF) tests in several e⁻ & ion beam facilities (JUDITH, TEXTOR, MARION).
- These experiments were carried out in parallel with extensive modelling of the complete tungsten tile assembly in the so-called Global Thermal Model (GTM) [2].

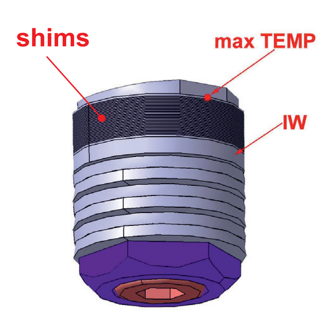


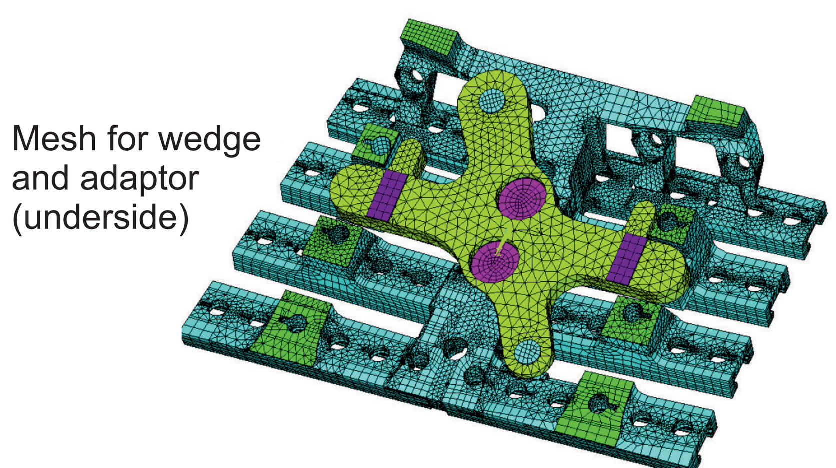
- HHF nominal values: 7-9 MW/m^2, E_{dep} ≤60 MJ/m^2

Goal: understand the heat flow from the plasma-facing surface through the supporting structure down to the base plate of the JET MkII divertor sufficiently to be able to later interpret operational data from the torus.

2 GTM Model

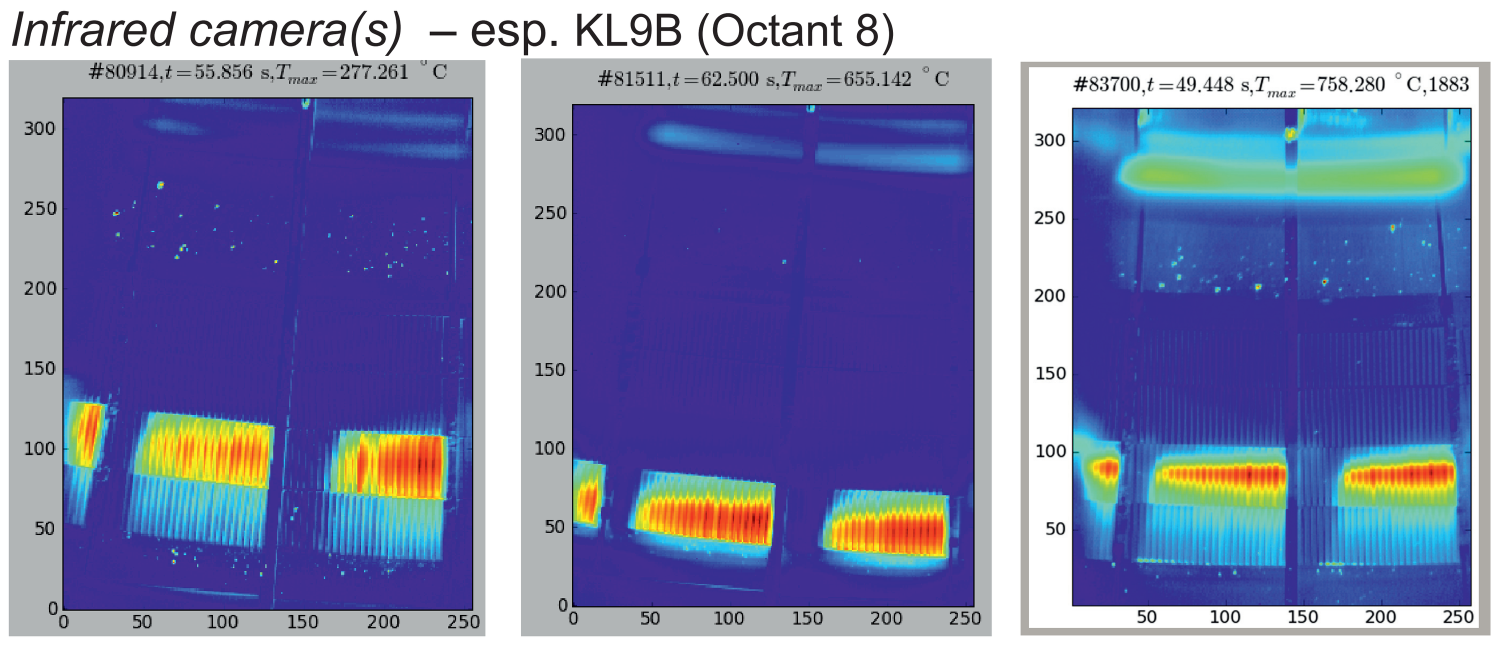
- 3D Finite Element (FE) model, no simplifications, T-dependence
- Radiation significant in the cooling process: ε_W=0.34 around 2000°C
- Special attention to contact layers: $\lambda_i \in$ (2.1-36 W/(m.K)) at 2000°C
- Detailed modelling of clamping arrangements: $\lambda_{shims} = \lambda_{Makor\text{-}11mm}$





3 Experimental

Infrared camera(s) – esp. KL9B (Octant 8)

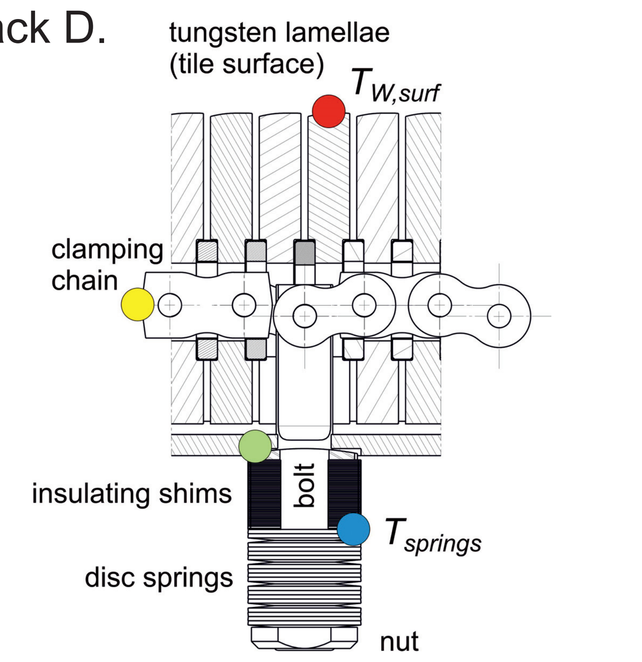


JPN 80914 (3MW ICRF)-stack C   JPN 81511 (4.5MW NBI)-stack D   JPN 83700 (12MW NBI)-stack C

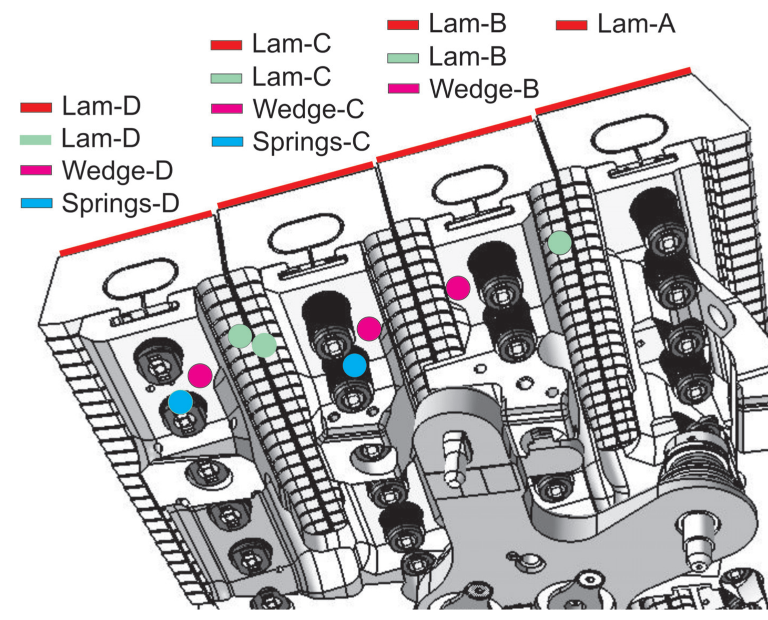
- Provide the temperature of the plasma-facing surface of the tile (check boundary condition)

Thermocouples (under tile 5) – KD1D (Assemblies)

The bulk W divertor has three modules equipped with thermocouples (TC) at positions shown in the picture above, right column. Some redundancy is provided, for instance between different modules for the temperature of tungsten at the bottom of stack C or of stack D.



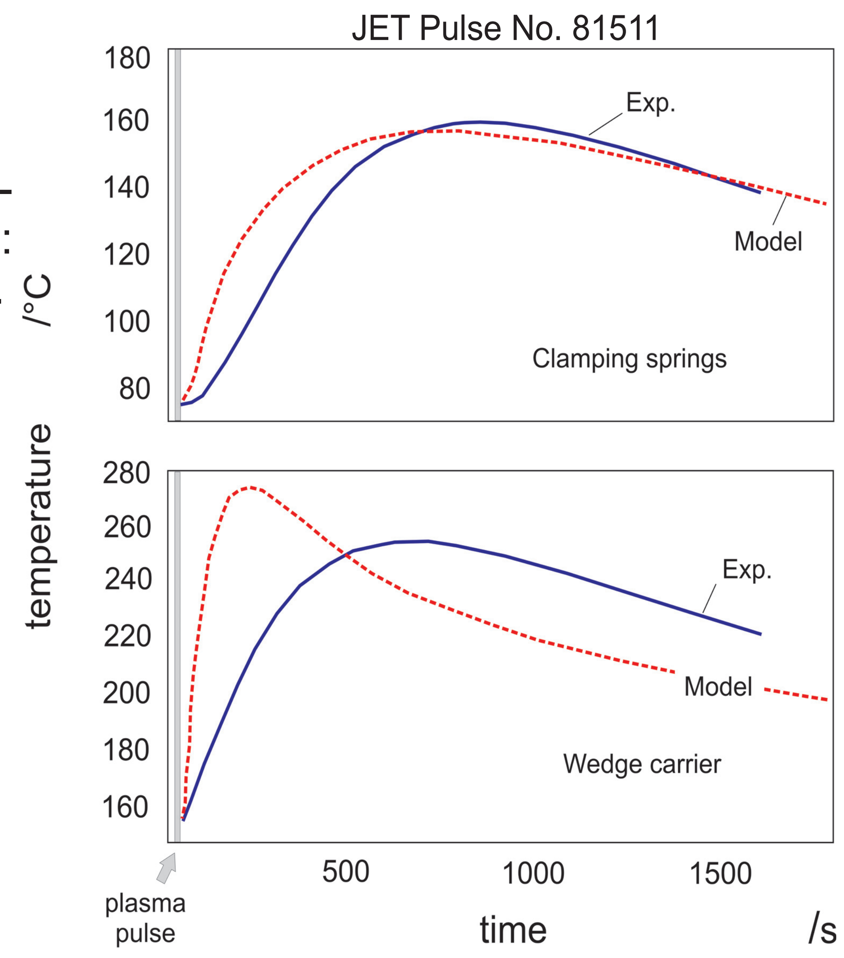
Thermocouple locations on prototypes



Thermocouple locations in the torus

4 Results

- Temperature of the clamping springs (vulnerable component) close to model temperature: systematic correction to measurement +30°C. Characteristic time in very good agreement too: better than 10%
- Wedge carrier wings: +10/+65° in the range 150-300°C but different time constant !
- Surface of the tungsten tile: deviations in the order of 100°C
- Cooling of all parts under the same temperature curve (envelope) from ~500°C down to ~200 °C.



Pulse	Bt /T	Ip /MA	$n_e\,d\ell$ (x10^{19}) /m^{-2}	T_e /keV	Z_{eff}	P_{NBI} /MW	P_{ohm} /MW	P_{rad} /MW	f_{rad}	P_{sht} /MW	P_{div} /MW	P_{idiv} /MW	P_{odiv} /MW
82394	2.4	2.0	17.0	3.2	1.85	12.10	0.41	5.00	0.40	0.10	6.91	2.3	4.63
81511	2.5	2.5	10.5	2.0	2.60	4.40	1.40	2.25	0.39	0.10	3.23	1.1	2.16
81510	2.5	2.5	11.5	2.0	2.60	4.45	1.43	2.45	0.42	0.09	3.09	1.0	2.07

Pulse	Δt /s	E_{dep} /MJ.m^{-2}	Config.	Stack	T_W /C (init.)	T_W /C (fin.)	ΔT_W /C (thermocouple)	$T_{W,surf}$ /C (init.)	$T_{W,surf}$ /C (fin.)	$\Delta T_{W,surf}$ /C (measured)	$\Delta T_{W,surf}$ /C (model)	T_{wedge} /C (init.)
82394	5.0	19.3	V5 LT	D	116	292	176	120	—	—	600	126
81511	15.0	25.9	V5	D	155	355	200	207	894	687	560	155
81510	15.0	24.8	V5	C	161	350	189	161	700	539	510	161

T_{wedge} /C (max.)	ΔT_{wedge} /C (measured)	ΔT_{wedge} /C (model)	t_c (wedge) /s (meas.)	t_c (wedge) /s (model)	$T_{springs}$ /C (init.)	$T_{springs}$ /C (max.)	$\Delta T_{springs}$ /C (stack D,meas.)	$\Delta T_{springs}$ /C (stack D, model)	t_c (springs) /s (meas.)	t_c (springs) /s (model)
202	76	130	700	200	70	160	90	120	800	800
253	98	165	650	190	76	159	83	115	850	800
240	79	140	700	190	—	—	—	105	600	750

5 Conclusions

- Excellent to fair agreement on the temperature of different components. The time constants to reach a common temperature show deviations from the model.
- The experimental behaviour of the row of bulk tungsten tiles during plasma operation is close to design values in a wide range of operational parameters with deposited energy densities around and slightly above 30 MJ/m^2.
- The tile is designed for a maximum local temperature of the plasma-facing tungsten of 2200°C and a maximal energy deposition of 60 MJ/m^2 (+0/-10%).

[1] Ph. Mertens et al., Physica Scripta **T145** (2011) 014002 (7pp)
[2] S. Grigoriev et al., Fusion Eng. Des. **84** (2009) 853–858

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